

InnovationXLab CarbonX Summit

Carbon Capture, Utilization, and Sequestration

Thursday, October 22, 2020



Moderator & Panelist
Dr. Grant Bromhal

*Senior Fellow, Geological &
Environmental Systems*
**National Energy
Technology Laboratory**



Panelist
Dr. Richard Esposito

R&D Program Manager
Southern Company



Panelist
Dr. Scott Chen

*President and Chief
Executive Officer*
**Carbon Capture
Scientific, LLC**



Panelist
Marc Witkowski

*Alliance Manager, Business
Development*
**Los Alamos National
Laboratory**



Panelist
Ben Bloys

*Strategic Planning &
Business Manager*
**Chevron Energy
Technology Company**

InnovationXLab CarbonX Summit

Carbon Capture, Utilization, and Sequestration



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Senior Fellow, Geological & Environmental Systems
National Energy Technology Laboratory

Carbon Capture and Storage Technology Overview



Grant Bromhal, Senior Fellow for Geosciences
National Energy Technology Laboratory, Pittsburgh, Pa

Carbon Capture, Utilization, and
Sequestration Panel

*2020 Virtual DOE InnovationXLab
CarbonX Summit*

Solutions for Today | Options for Tomorrow



Acknowledgements

- Dan Hancu
- Jan Fleckel
- Mark McKoy
- Bob Dilmore
- Mike Matuszewski

Capture & Storage.. Integration

Carbon Capture

2017

Large Capture
Pilots Initiated

2020

R&D Completed for Carbon Capture
2nd Generation Technologies

2022

Carbon Capture FEED
Studies Completed

2025

Integrated CCS
Projects Deployed

2035

Transformational
technologies available
for broad commercial-
scale deployment

Carbon Storage

2017

Initiate Storage
Feasibility for
Integrated CCS

2022

Commercial-scale
storage complexes
characterized

<https://netl.doe.gov/2020CCUS-proceedings>

Carbon Capture Program.. Mission

- **Mission**

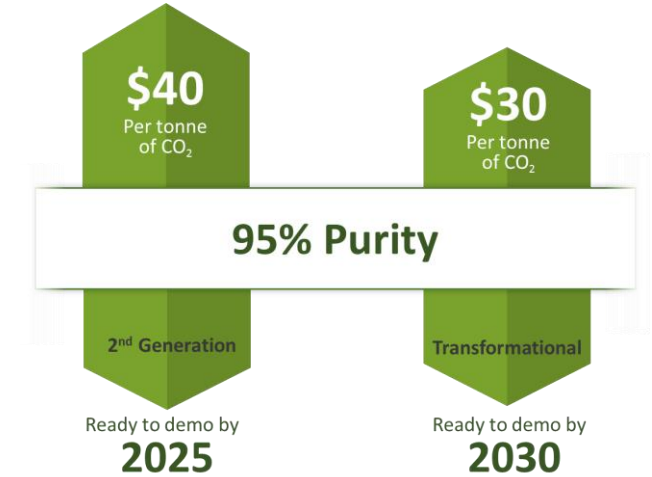
- Develop advanced cost-effect CO₂ capture technologies throughout the power-generation sector
- Ensure the U.S. will continue to have access to safe, reliable, & affordable energy from fossil fuels

- **Drivers/Challenges**

- Coal-based & gas-based power are the 1st & 2nd largest stationary sources of CO₂ emissions
- Reduce CO₂ capital & operating costs
- Increase efficiency & reduce cost of CO₂ compression

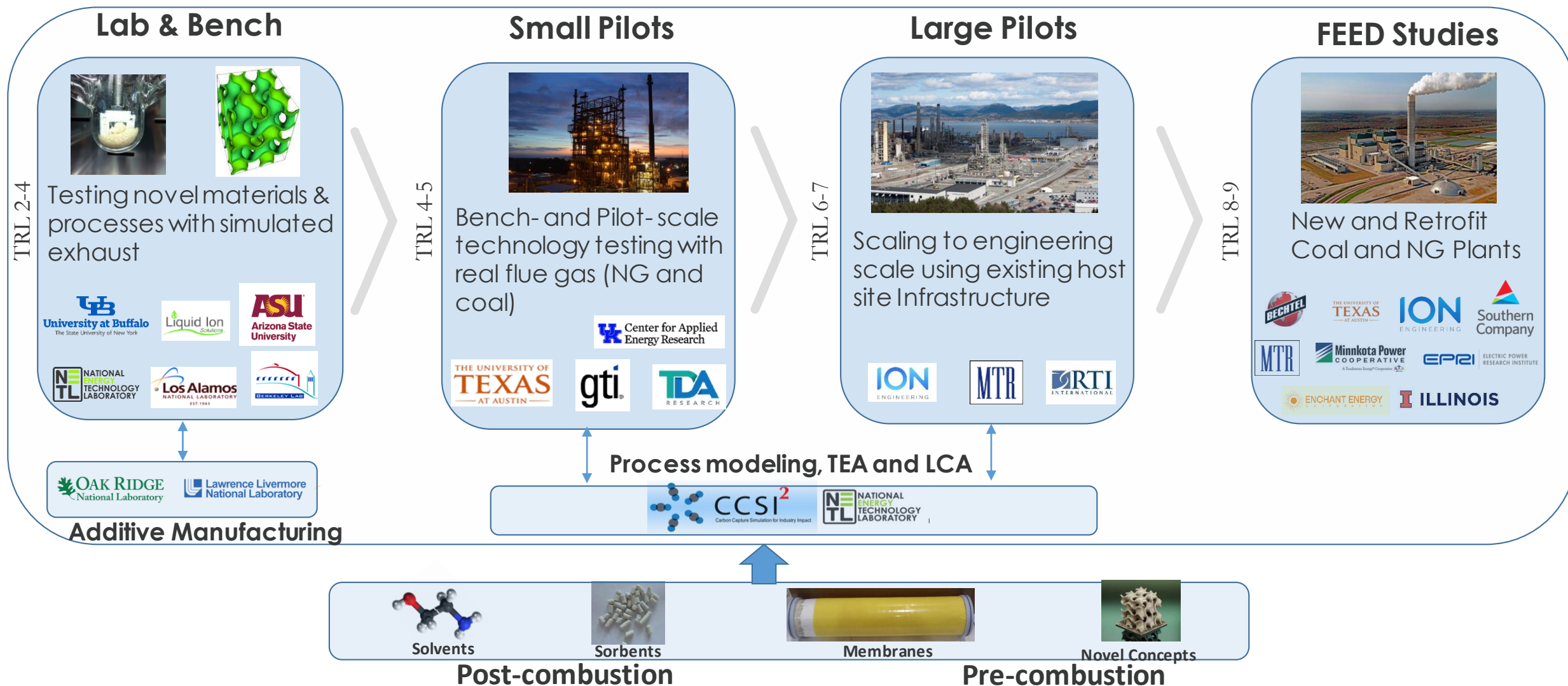
- **Goal & Metrics**

- By 2030, COE at least 30% lower than a supercritical PC with CO₂ capture



National Carbon Capture Center
Photo Source: Southern Company Services

Carbon Capture.. Program Structure



CCSI²: Accelerating Rate of RD&D



National Labs



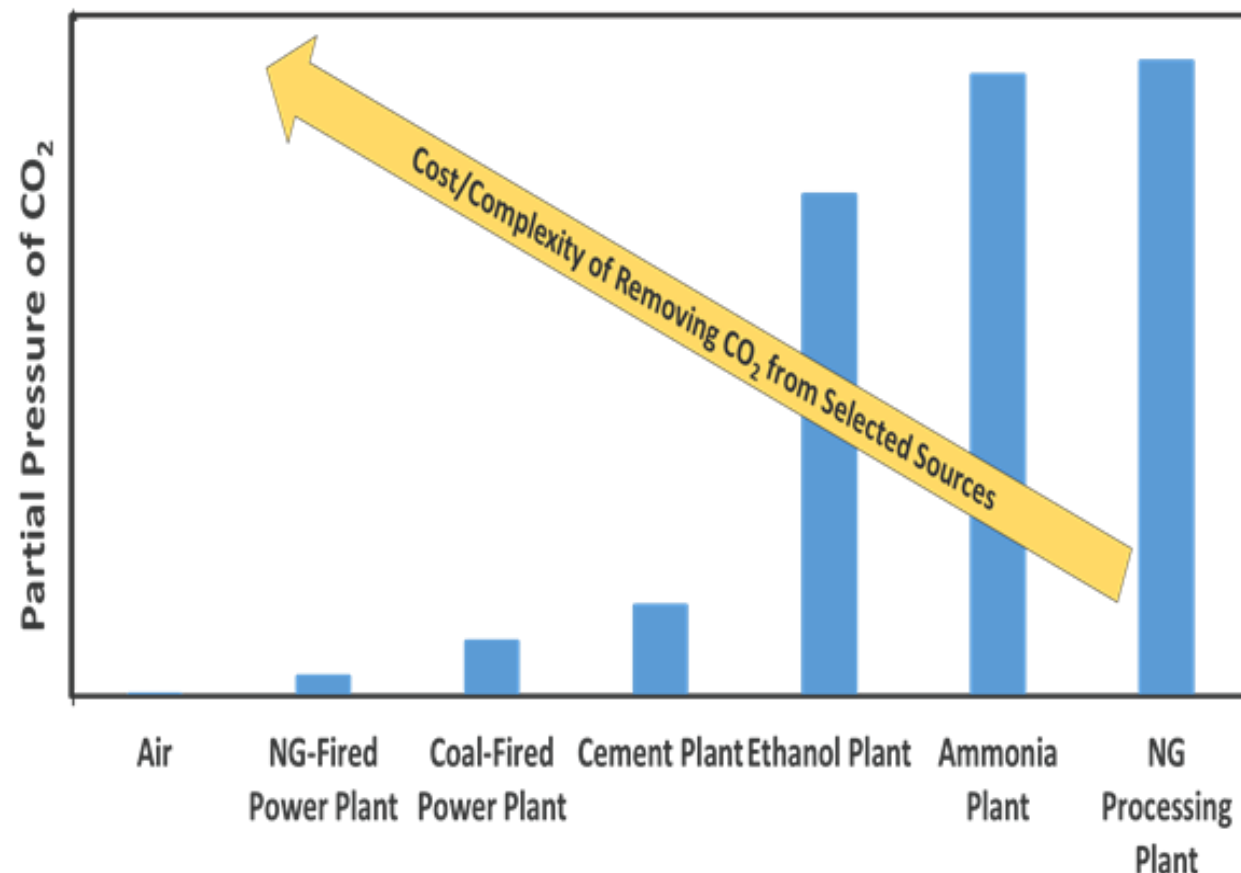
Academia



Industry



Carbon Capture.. New Challenges



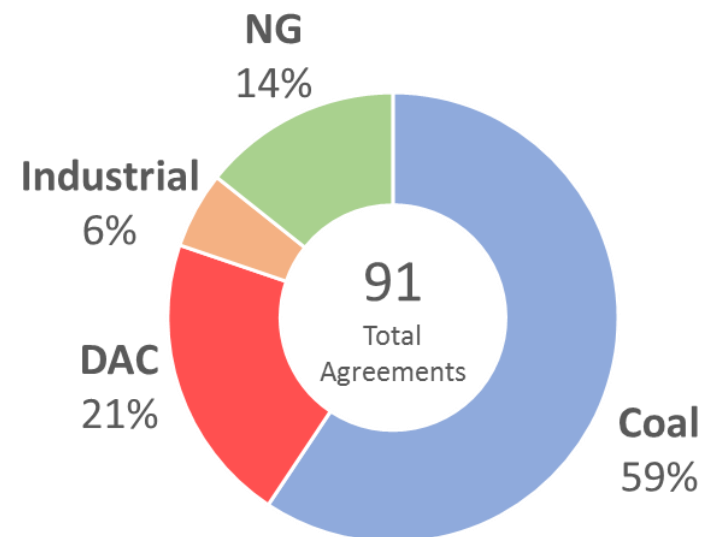
- **DAC..**
- **NGCC..**
- **Industrial..**
- **Coal FIRST..**

Increased cost and complexity due to low CO₂ %

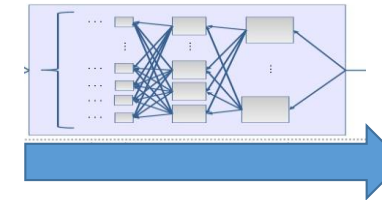
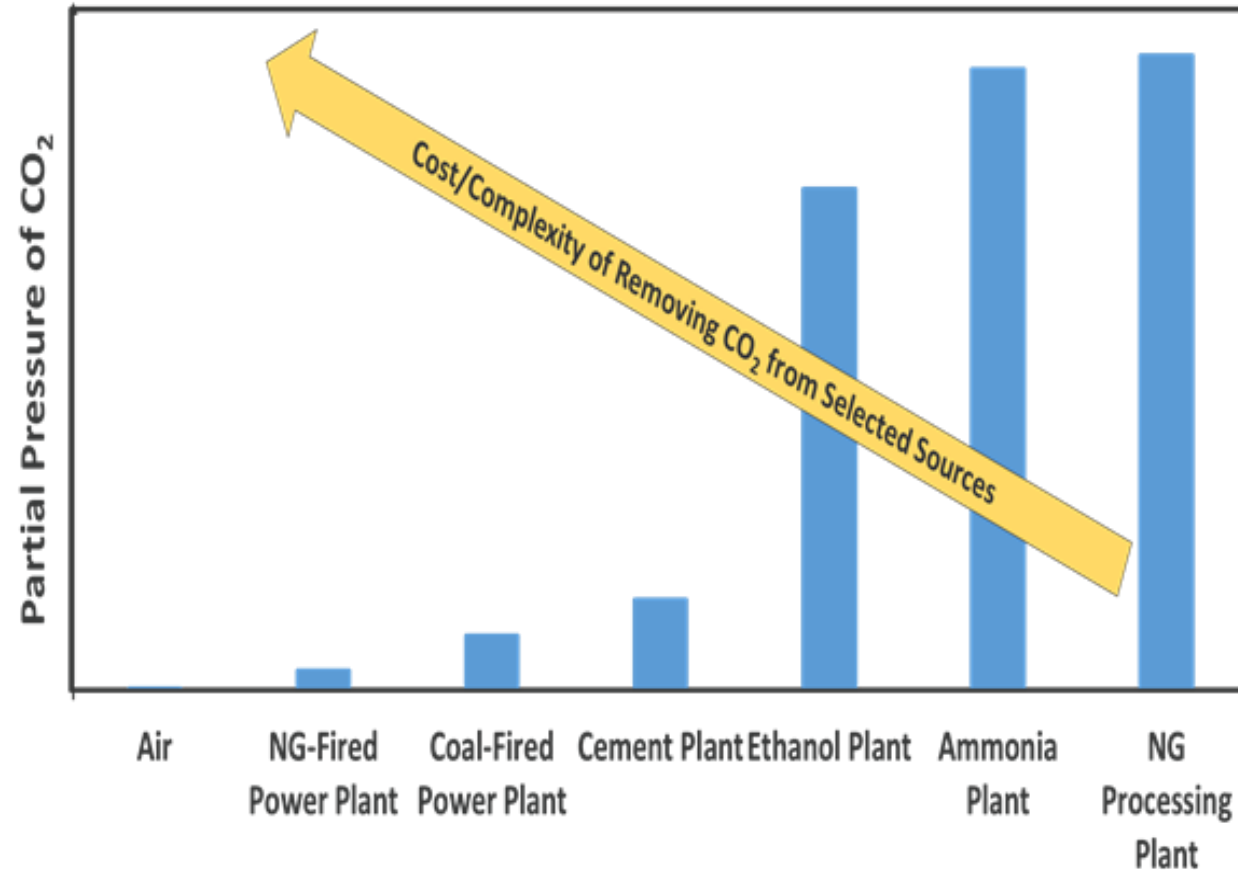
Increased oxidative degradation due to higher O₂ %

Heat integration & impurities

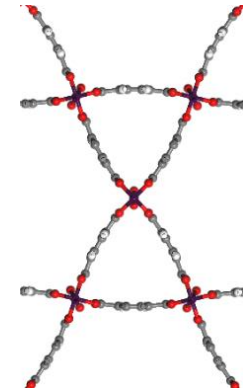
Load following operation & low utilization factors



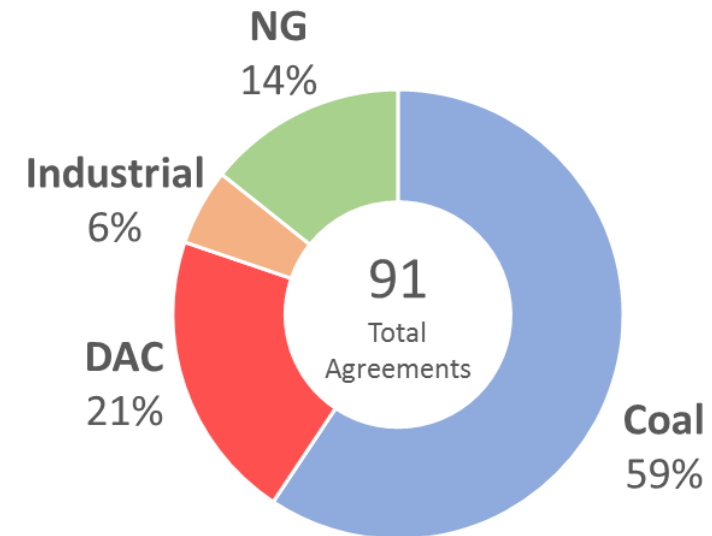
Carbon Capture.. New Challenges



OPTIMUM MOF



DIRECT AIR CAPTURE



Develop technologies for commercial readiness beginning in 2025 that ensure:

- **Safe**, secure, efficient, and **affordable** CO₂ injection
- Containment in storage complexes in **diverse** geologic settings

Goals:

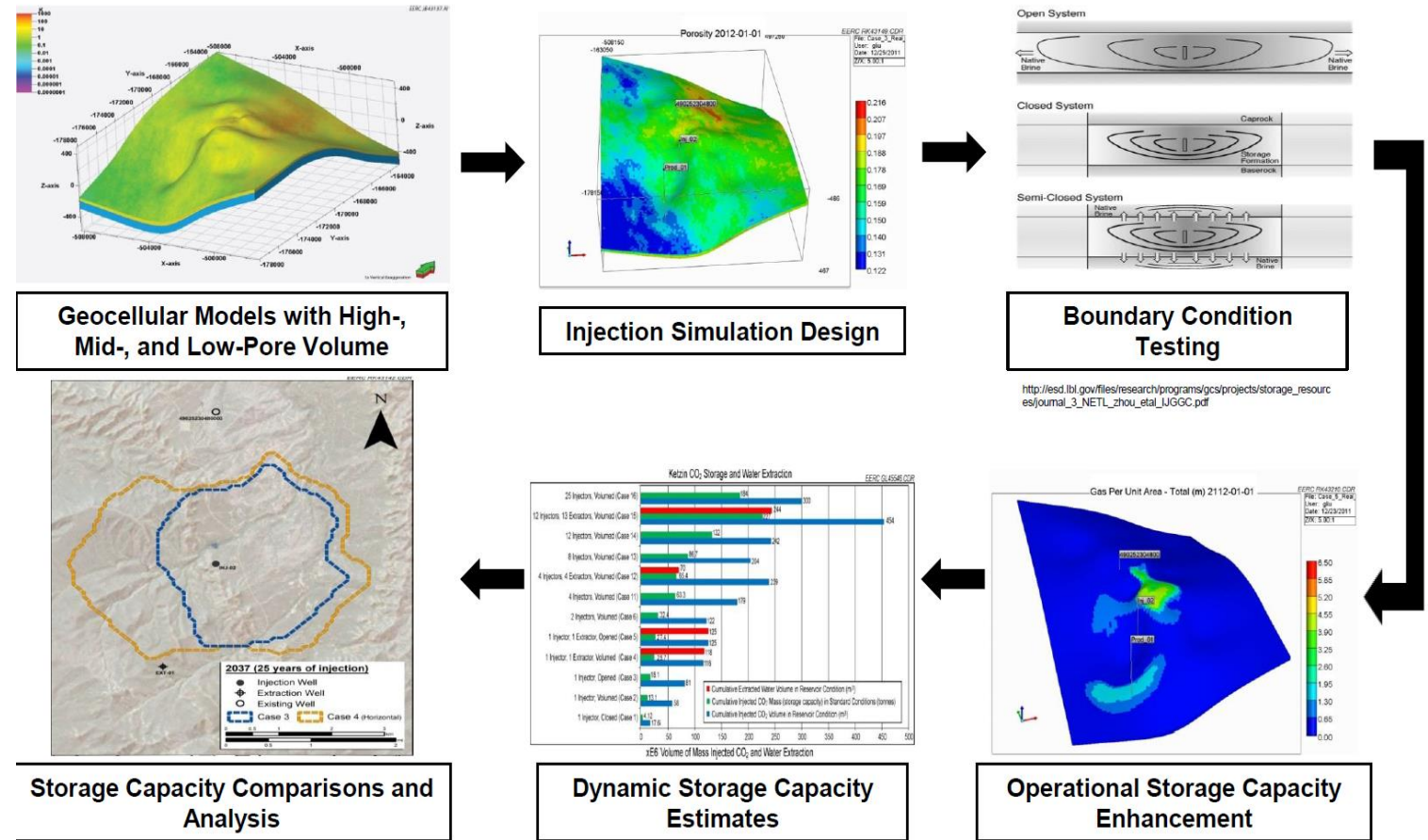
- Reduce project risks
- Reduce project costs
- Field validation and large-scale injection efforts
- Raise awareness that geologic storage is a viable and safe approach to reducing CO₂ emissions

Carbon Storage.. Technology R&D

- Assessing onshore and offshore storage capacity
- Advanced understanding of CO₂ behavior in subsurface
- Novel sensors for monitoring
- Novel well sealing and remediation materials

Simulation Workflow

CO₂ Storage Resource in Saline Formations; EERC

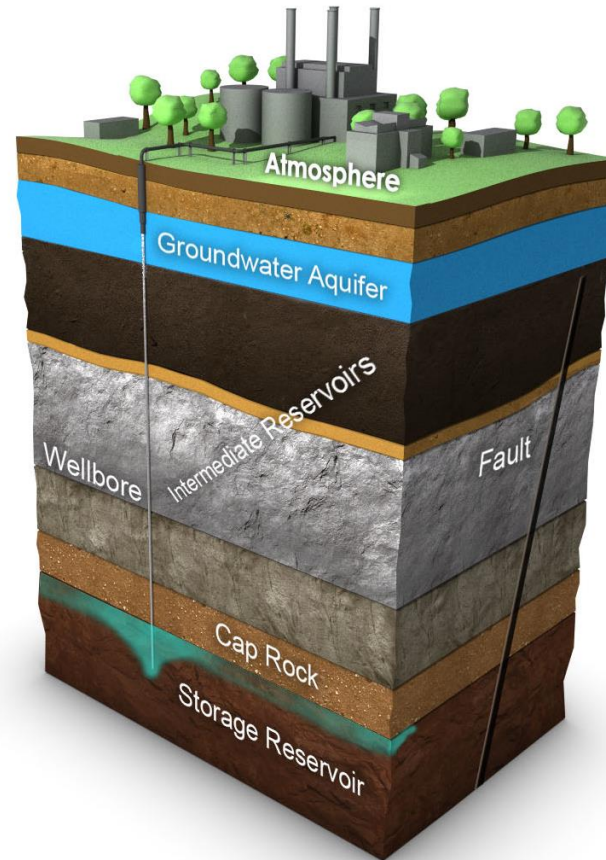


U.S. DOE's National Risk Assessment Partnership



NRAP leverages DOE's capabilities to quantitatively assess long-term environmental risks amidst significant geologic uncertainty and variability.

Technical Team



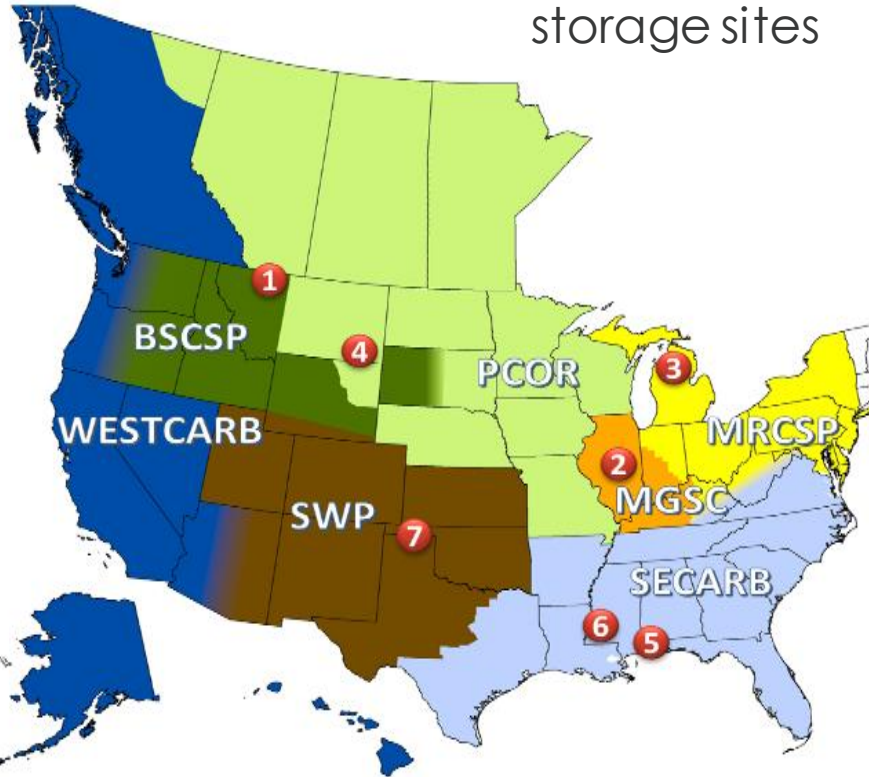
Stakeholder Group



Regional Field Sites

RCSP Field Projects

Important step towards
enabling 50+MMT scale
storage sites

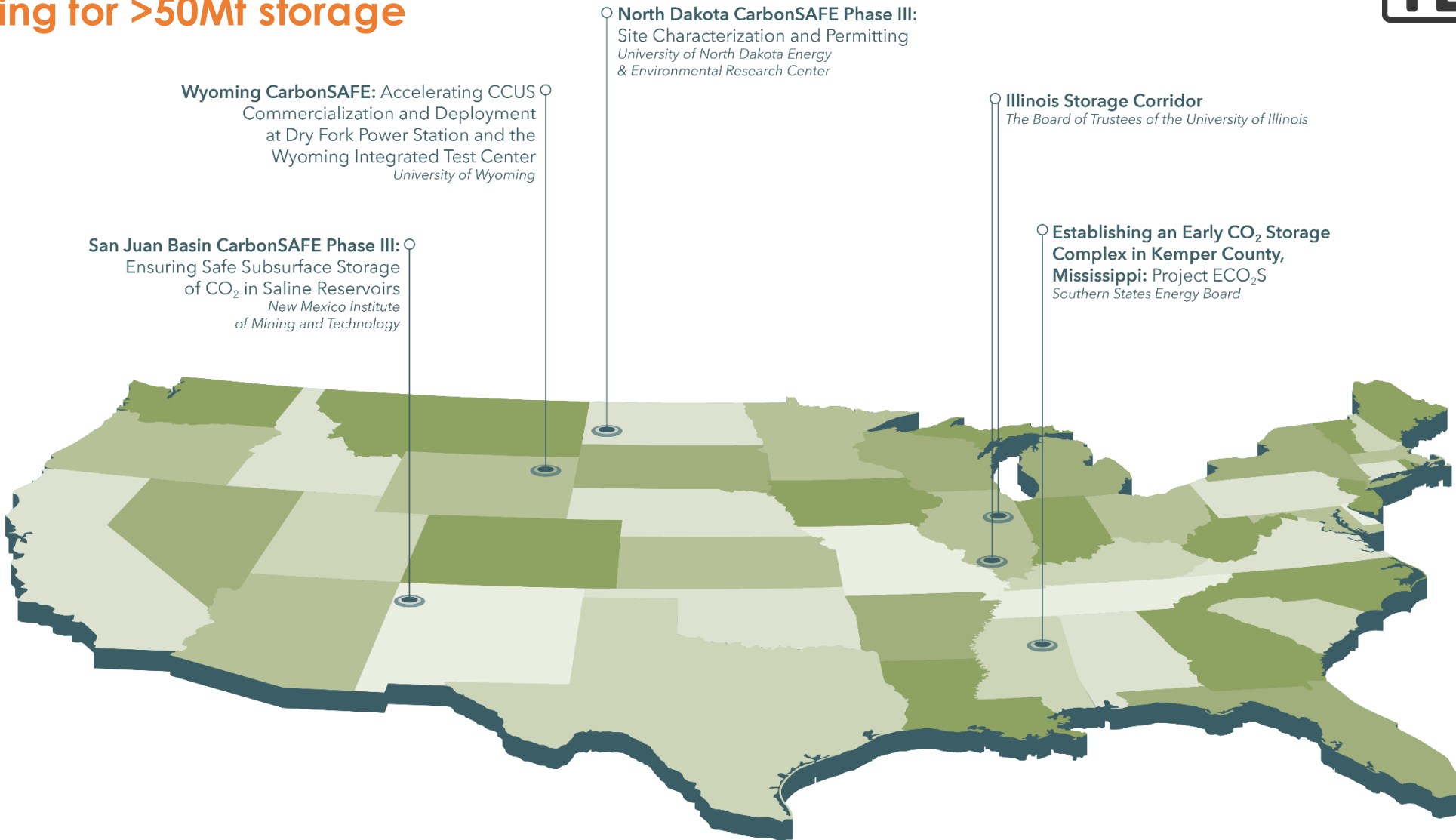


Best Practice Manuals

Number on Map	Project Name	Project Type	CO ₂ Source	Geologic Basin	Metric Tons of CO ₂ Stored
1	Big Sky Carbon Sequestration Partnership-Kevin Dome Project	Saline Storage	Kevin Dome (natural)	Kevin Dome	N/A
2	Midwest Geological Sequestration Consortium -Illinois Basin - Decatur Project	Saline Storage	ADM Ethanol Production Facility	Illinois Basin	999,215
3	Midwest Regional Carbon Sequestration Partnership - Michigan Basin Project	Enhanced Oil Recovery	Core CO ₂ Services, LLC Natural Gas Processing Facility	Michigan Basin	1,553,626
4	The Plains CO ₂ Reduction Partnership-Bell Creek Field Project	Enhanced Oil Recovery	Conoco Phillips Lost Cabin/Madden Natural Gas Processing Plant	Powder River Basin	2,982,000
5	Southeast Regional Carbon Sequestration Partnership - Citronelle Project	Saline Storage	Southern Company's Plant Barry Coal-Fired Power Plant	Interior Salt Basin, Gulf Coast Region	114,104
6	Southeast Regional Carbon Sequestration Partnership -Cranfield Project	Enhanced Oil Recovery/ Saline Storage	Jackson Dome (natural)	Interior Salt Basin, Gulf Coast Region	4,743,898
7	Southwest Regional Partnership on Carbon Sequestration -Farnsworth Unit Project	Enhanced Oil Recovery	Arkalon Ethanol Plant (Liberal, KS) Agrium Fertilizer Plant (Borger, TX)	Anadarko Basin	791,593

CarbonSAFE Phase III Locations

Preparing for >50Mt storage



Thank You!

VISIT US AT: www.NETL.DOE.gov



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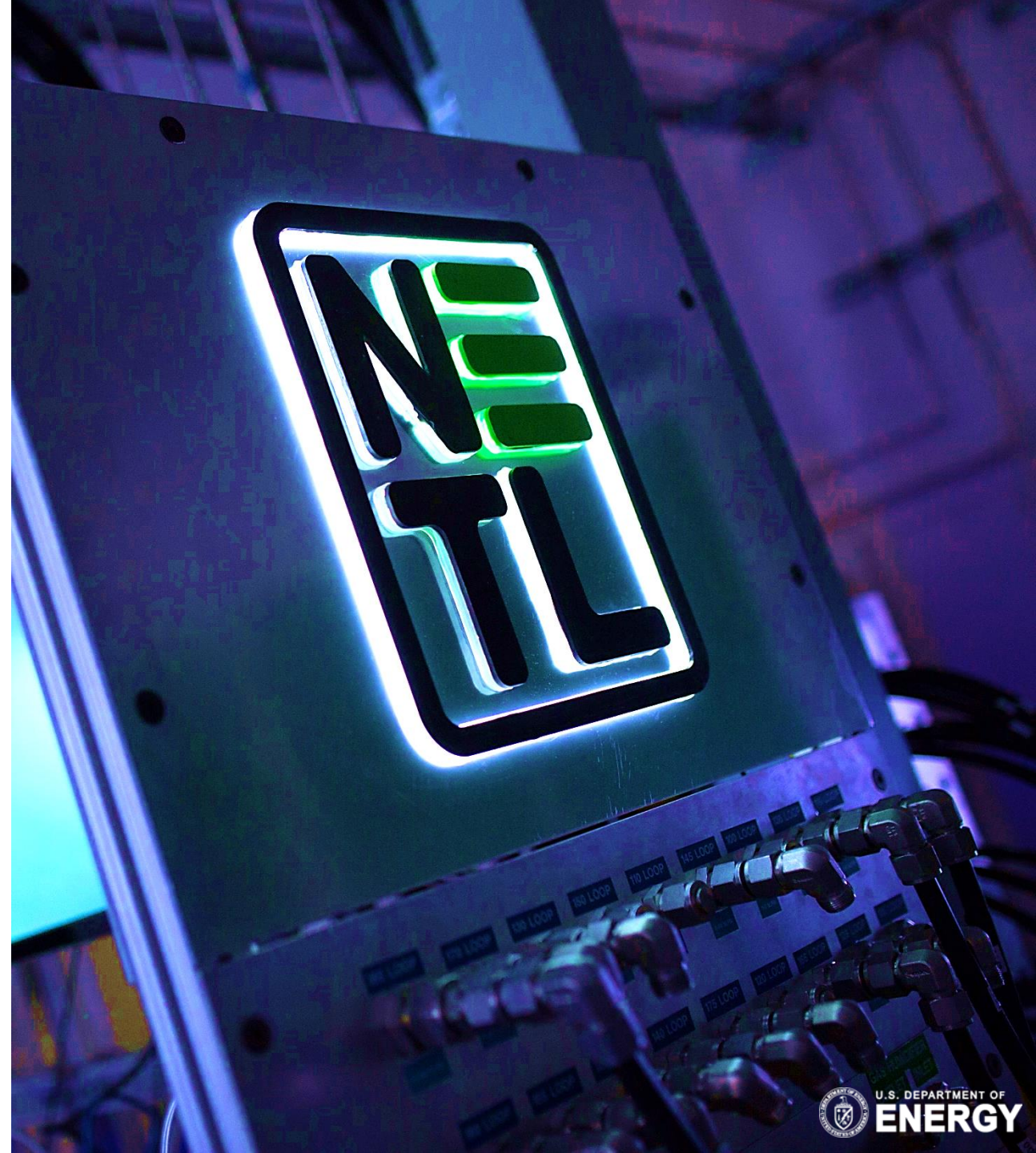


@NationalEnergyTechnologyLaboratory

CONTACT:

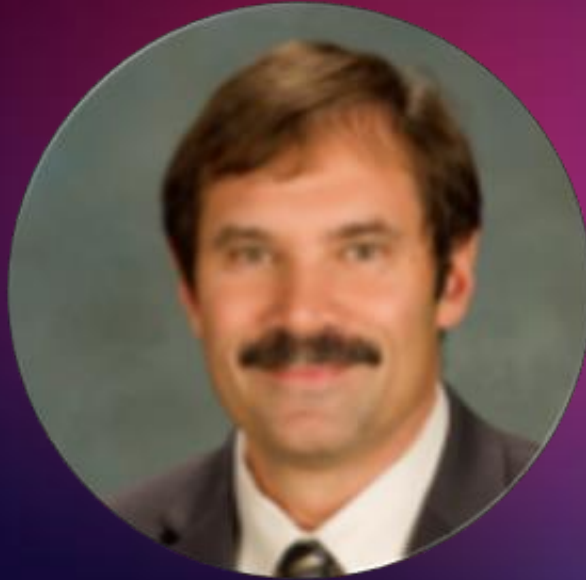
Grant Bromhal

Grant.Bromhal@netl.doe.gov



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Panelist

Richard Esposito

*R&D Program Manager,
Geosciences & Carbon Management*
Southern Company

Prepared for:

U.S. Department of Energy – National Energy Technology Lab

Presented as part of:

Carbon Capture, Utilization and Sequestration

2020 Virtual DOE InnovationXLab CarbonX Summit

Prepared by:

Richard A. Esposito

R&D Program Manager – Geosciences & Carbon Management

Southern Company, Birmingham, Alabama



Providing clean, safe, reliable, affordable energy and customized solutions



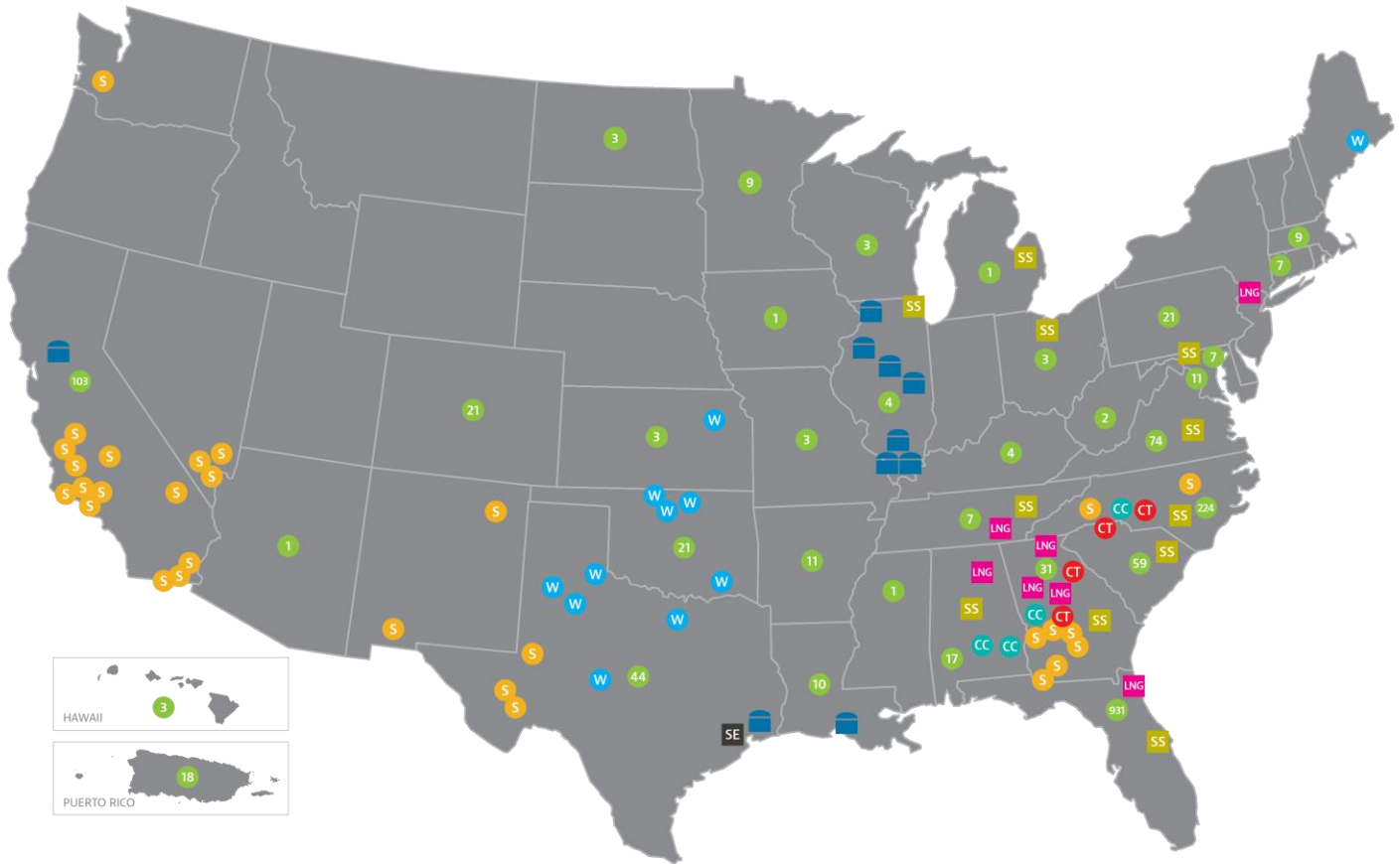
Service territories

- Electric
- Gas



Gas pipelines

- Southern Natural Gas
- Southern Company Gas
- Pipeline projects



Southern Power

- CC Combined-cycle facility¹
- CT Peaking facility
- B Biomass facility
- S Solar facility
- W Wind facility

Southern Company Gas

- LNG LNG facilities
- SE Sequent Energy Management
- SS SouthStar
- Natural gas storage

PowerSecure

- # Owned and managed sites per state

¹In November 2018, Southern Power agreed to sell its combined-cycle facility in Mankato, Minnesota.

Capabilities in
50 States

7
Electric & Natural
Gas Utilities

9 Million
Customers

Approximately
29,000
Employees

Approximately
44,000 MW
of Generating Capacity

Industry-Leading Culture of Innovation – Hand-in-Hand with National Labs



William B. Harrison, Ph.D.



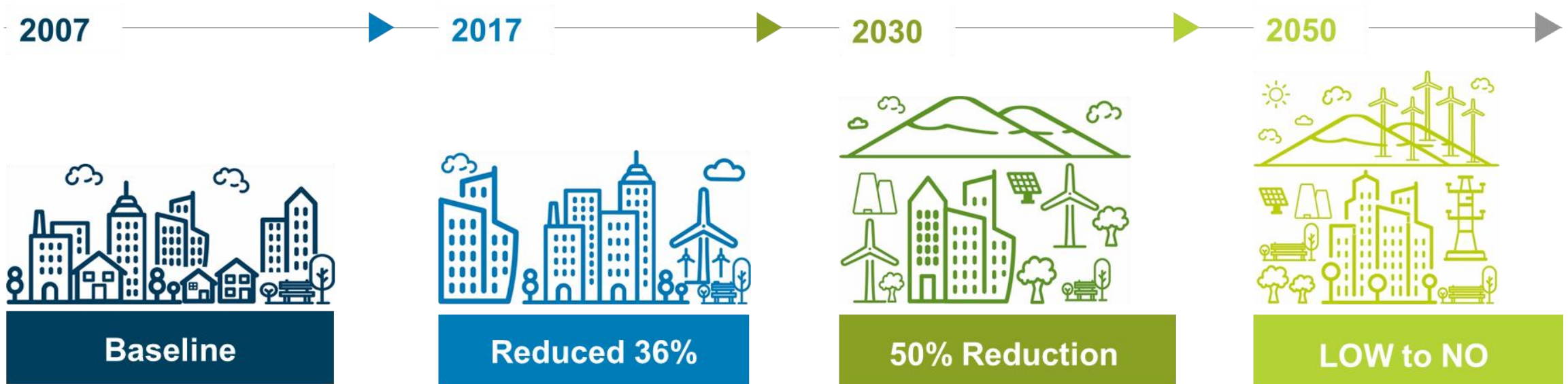
- Dedicated research organization **founded in 1969**
- Diverse research portfolio for **energy production, delivery & use**
- Collaboration with DOE/NETL, utilities, universities, technology developers
 - ✓ External cost sharing leverages investment
 - ✓ Full-member/engaged advisors of EPRI
 - ✓ Anchor sponsor of EPRI/GTI Low-Carbon Resources Initiative
 - ✓ Prolific **U.S. Department of Energy** partner



Southern Company's Net-Zero Commitment is Driven by R&D

Our energy strategy includes the continued development of a diverse portfolio of energy resources to serve customers and communities with a focus on reducing greenhouse gas emissions

Greenhouse Gas Emissions Reduction Goals



National Carbon Capture Center, Wilsonville, Alabama



- 110,000+ test hours of testing over last decade
- 60+ technologies tested / developers from 7 countries
- Post-combustion accomplishments:
 - ✓ Continuous expansion – alternative regeneration, gas injection, analytical support
 - ✓ Advanced solvents, membranes, solid sorbents
 - 16 technologies in queue to test / 7 technologies scaled up (or ready) to 10+ MW



Reduced cost of CO₂ capture from fossil generation by 1/3

Oct. 1, 2020 – 5-Year Agreement Renewal / \$140 Million
Expanding scope to CO₂ capture for **natural gas** power,
CO₂ utilization, **direct air capture**

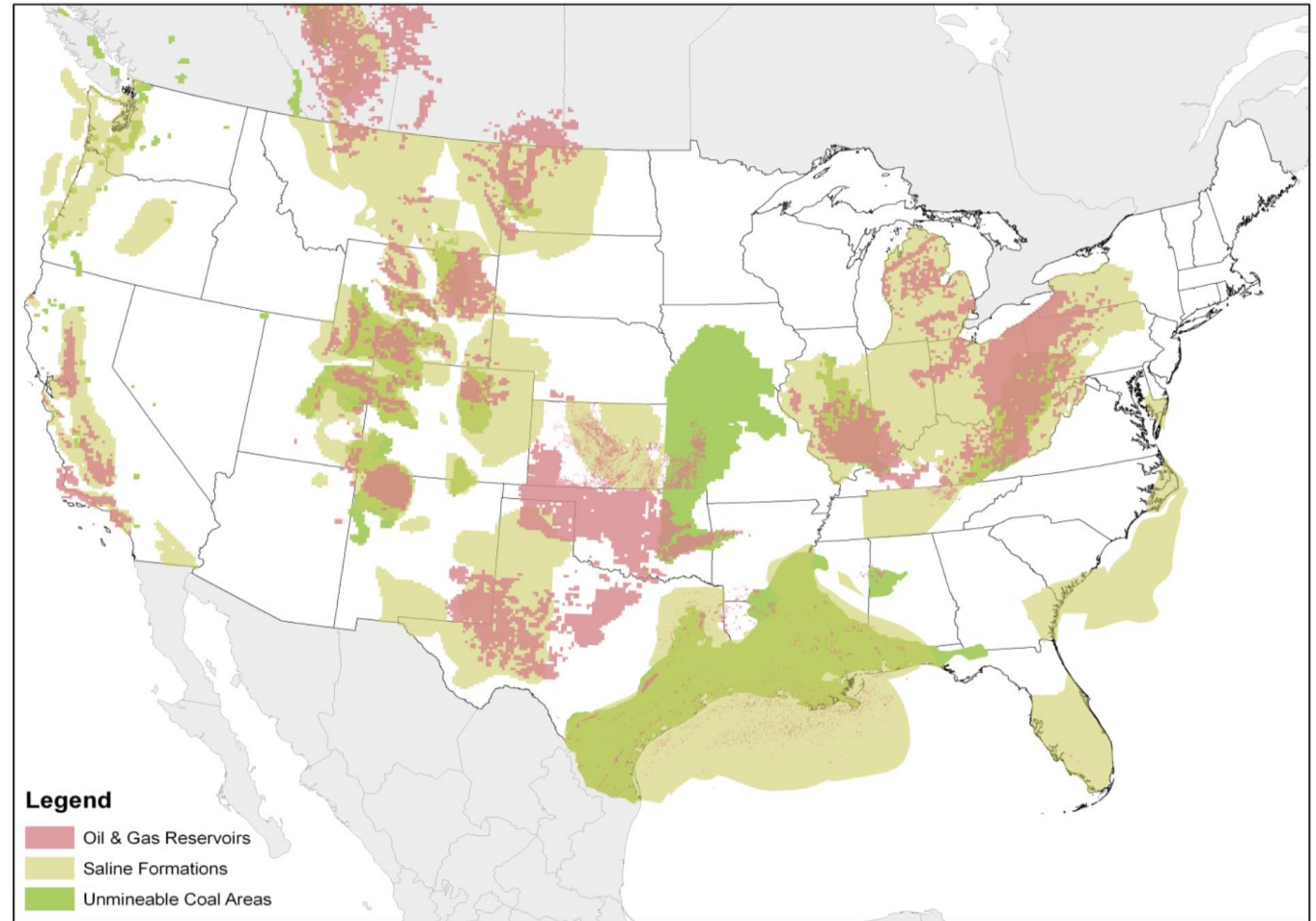
Value Proposition – National Labs and Southern Company



- ✓ Leading exploratory, early-TRL research and experiments
- ✓ Deep bench strength in fundamental science
- ✓ Technical expertise that drives scale-up and commercial adoption
- ✓ Ease of collaboration with private industry
- ✓ Significant leverage by supporting public-private cost-share

NETL – Industry Partnerships are Filling in the Gaps with CO₂ Storage

- RCSP initiative and the regional initiatives to accelerate CCUS
 - Regional teams and project development
- CarbonSAFE initiative
 - Source-sink matching
 - Site characterization & permitting
- Carbon Storage Atlas
- NRAP tools
 - Risk analysis
- International CCUS outreach
 - Collaborations



U.S. Assessment of Geologic CO₂ Storage Potential
Source: [U.S. EPA Archive](#)

Future Strategic R&D Needs Considering Variable Injection Rates

Based on age, depreciation, dispatch and fuel costs, utilities may focus on decarbonizing natural gas as “backup dispatch” to renewables vs. “baseload power”

- Innovation with injection well design
- Issues with wellbore integrity
- Monitoring systems
- Issues with near wellbore reservoir damage
- Issues with induced seismicity
- Impacts to injectivity and long-term storage capacity
- Understanding the options with saline vs. CO₂-EOR

Thank you for the opportunity to participate today



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Panelist

Dr. Scott Chen

President and Chief Executive Officer
Carbon Capture Scientific, LLC

Gas Pressurized Stripping (GPS) Technology from Concept to Commercialization

Carbon Capture Scientific, LLC.

Shiaoguo (Scott) Chen

October, 2020

About Carbon Capture Scientific, LLC (CCS)

- ❑ An early stage small company located in Pittsburgh, PA
- ❑ Technology development based on transition from thermodynamic analysis, to process simulation, to bench-scale prototyping
- ❑ Research focus on CO₂ capture technologies for pre- and post-combustion gas streams for the past ten years
- ❑ Two patents generated in past several years through a gas separation technology projects
- ❑ GPS technology is being commercialized for different applications



CARBON CAPTURE SCIENTIFIC, LLC.

Development of a Novel Gas Pressurized Stripping (GPS)-Based Technology for CO₂ Capture from Post-Combustion Flue Gases

Team Members:

Carbon Capture Scientific, LLC.

CONSOL Energy Inc.

Nexant Inc.

Western Kentucky University

HiGee USA Inc.

Funded by NETL Through Contract: DE-FE0007567

Bench-Scale Test at National Carbon Capture Center



**National Carbon Capture Center
Birmingham, Alabama**



CCS's Bench-Scale Skid

GPS Technology

GPS ADVANTAGES:

- ❑ Applicable to existing facilities---only needs to modify the stripper
- ❑ Mature technology---only uses on-the-shelf process equipment
- ❑ High thermodynamic efficiency
 - High stripping pressure
 - Significantly reduced stripping heat
 - Reduced compression work
- ❑ ***Applicable to different solvents***
 - Tailored operating conditions according to solvents
 - Especially suitable for non-aqueous solvents

GPS APPLICATIONS

- ❑ CO₂ capture from any post-combustion flue gases (power plants, cement industry, refinery)
- ❑ CO₂ capture/separation from pre-combustion streams such as syngas
- ❑ CO₂ recycle for EOR—possibility of eliminating entire CO₂ compression
- ❑ Natural gas sweetening, especially when high pressure CO₂ is wanted.
- ❑ CO₂ separation for chemical processes (H₂, ethylene oxide, DMF, etc.)

GPS Technology Performance

- ❑ Overall parasitic power load is **<0.23kWh/kgCO₂**
- ❑ Energy penalty to power plant is **18%**
- ❑ SPC power plant with GPS have thermal efficiency of **32.2%**
- ❑ Capital cost is **<5% increase over the Baseline MEA case**
- ❑ LCOE of GPS process **97.4 mills/kWh (2007\$)** or CO₂ capture cost of **\$37.7/tonne (without TS&M)**
- ❑ *GPS technology has TRL level of conventional absorption/stripping processes*

Future Work and Collaborations

❑ Work with solvent developers to tailor solvents for specific applications

- Power plant flue gas CO₂ capture
- Cement Plant flue gas CO₂ capture
- Natural gas sweetening (*NETL HABEN Solvent*)
- Pre-combustion CO₂ separation from syngas (*NETL HABEN Solvent*)
- Recycled CO₂ separation/compression in EOR (*NETL HABEN Solvent*)

❑ Work with equipment developers on heat transfer integrated structured packing

- Additive manufactured structured packing at **Oak Ridge National Laboratory (ORNL)**



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*Alliance Manager,
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**Los Alamos
National Laboratory**



Panelist
Ben Bloys

*Strategic Planning &
Business Manager*
**Chevron Energy
Technology Company**



Chevron-LANL Alliance

Ben Bloys – Chevron
Marc S. Witkowski - LANL

Principals of Partnership/Collaboration

- Collaboration mechanisms formalized in Alliance for Advanced Energy Solutions - MOU signed Nov. 2004
- Umbrella CRADA with individual projects (PTS's), non-disclosure agreement (NDA) terms in place; terms for IP protection - complementary licensing MOU
- **Guiding principles:**
 - Mutual recognition of the two different organizational missions
 - Multi-year projects of mutual benefit
 - Structured approach to project selection, development, field-testing, and commercialization
 - Access best expertise in both organizations to solve problems
 - Joint advisory board that guides and reviews project performance twice per year

Alliance for Advanced Energy Solutions

Los Alamos National Laboratory and Chevron Energy Technology Company

- **Tactical Goals**

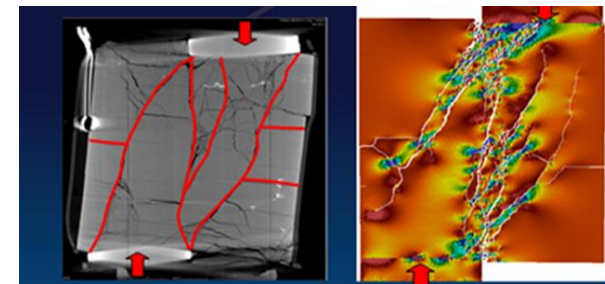
- Identify Chevron opportunities to apply Los Alamos technologies, or to jointly develop new technologies
- Maintain and expand Los Alamos capabilities
 - Solve key national problems
 - Develop capabilities for core missions
- Bridge the 'valley of death' for deployment/commercialization
- Build public/private partnerships to leverage into new programs & commercialization opportunities

- **Strategy**

- Focus on topics that benefit both organizations, while maintaining equal value proportions

- **Existing Projects**

- ~50 have been started
- 1 new project in FY 2020
- ~ 12 are ongoing in diverse topic areas
- ~ 5 projects at the commercialization/deployment phase

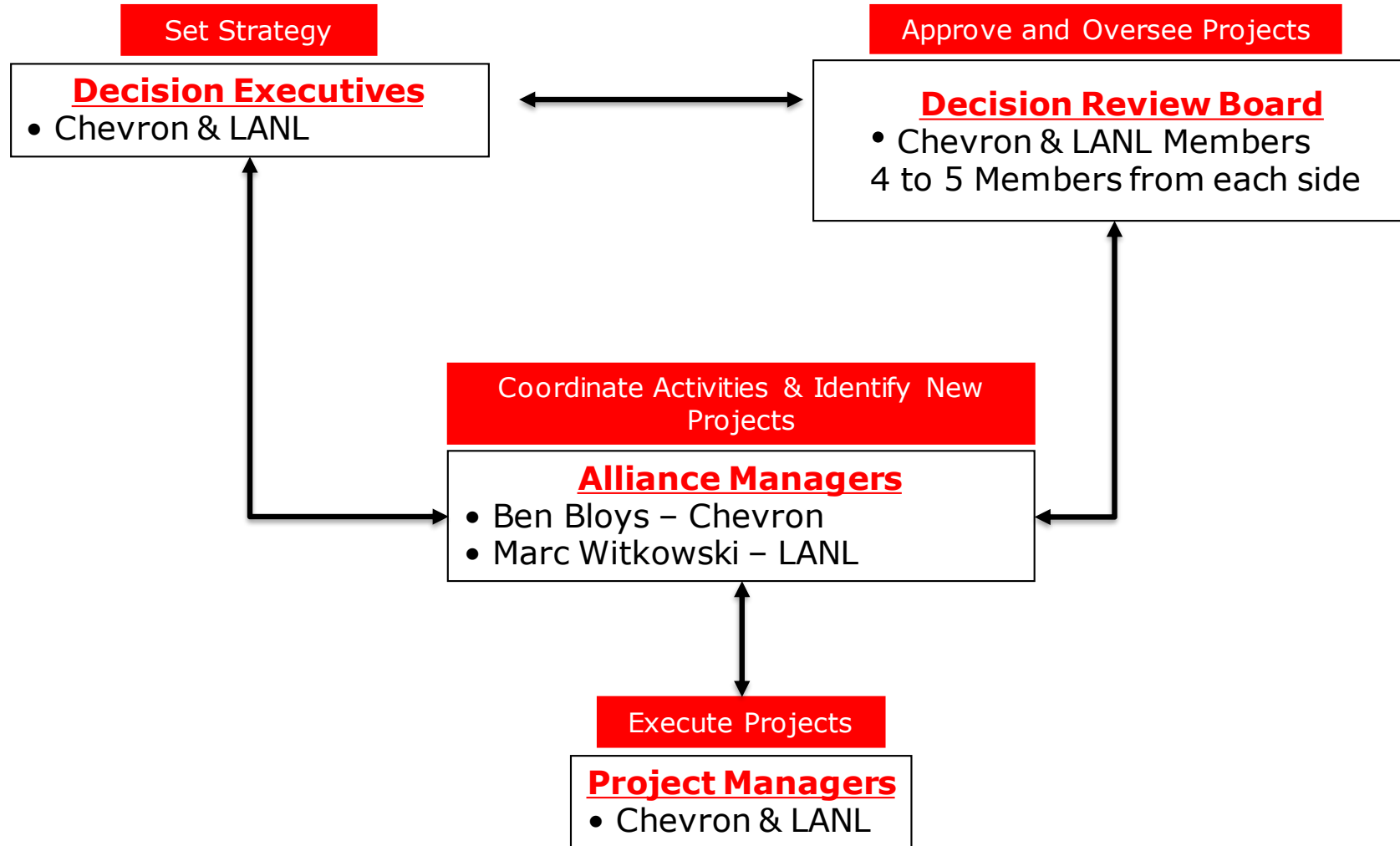


Making it work-

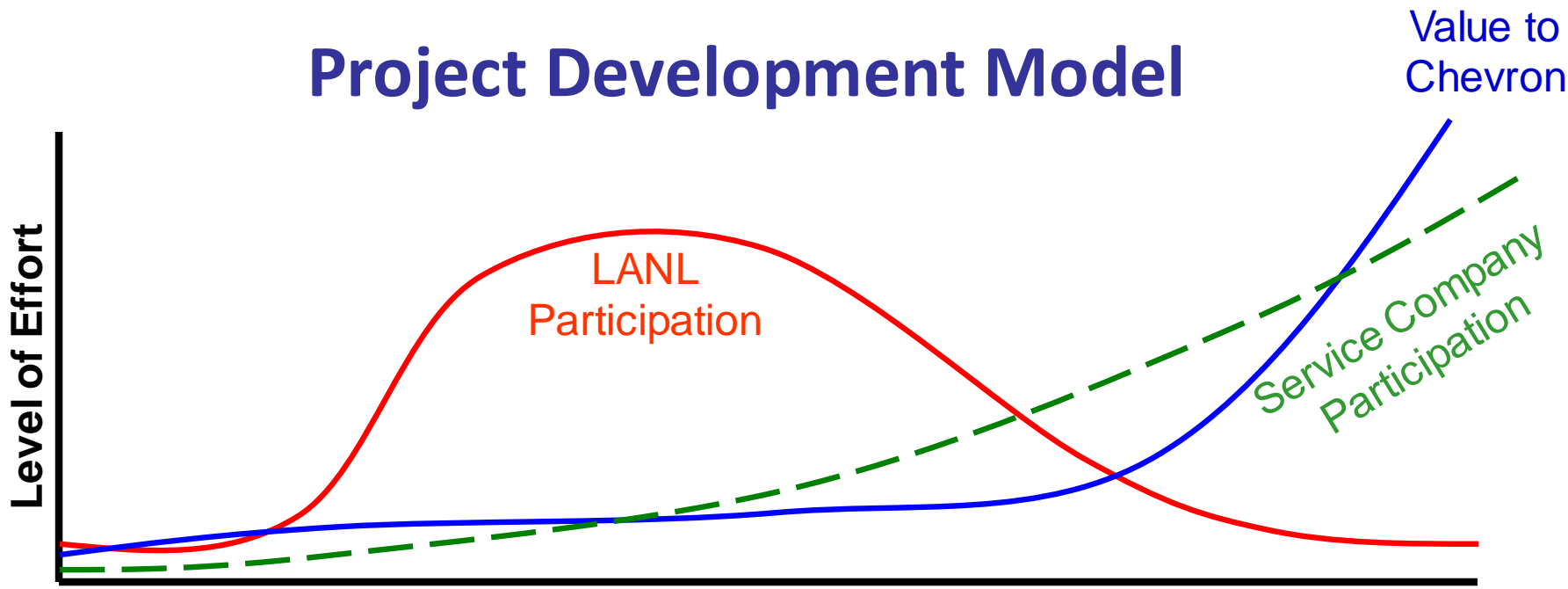
Merging two different cultures

- Process oriented versus creative/conceptual thinking - they actually mesh quite well.
- Align expectations and strategies at outset.
- Gently 'training' both bureaucracies about the needs of the Alliance, and about its cooperative nature
- Build structure to foster connections & trust across cultures – communication is the key!
 - ✓ Decision Review Board (DRB)
 - ✓ Alliance Managers
 - ✓ Project Leaders
 - ✓ Regular Meetings – weekly/semi-weekly

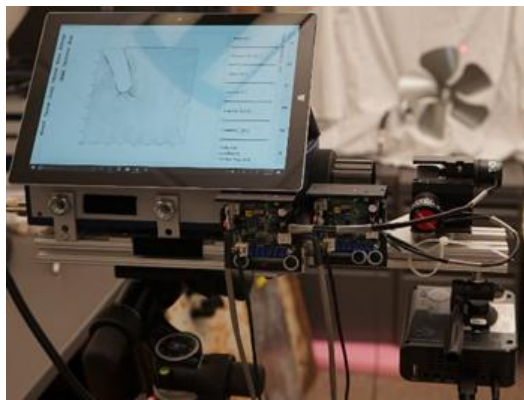
Alliance Operating Structure



Project Development Model



Phase: Problem ⇒ Concept ⇒ Feasibility ⇒ Develop ⇒ Field Test ⇒ Deploy



Collaborative Success

- Long Relationship- 16+ Years.
- Over \$100M dollars of private investment leveraging ~\$250M in government funded R&D.
- >300 patents filed.
- >100 students & post docs involved.
- > \$3M in license revenue.
- >\$100K invested in STEM Education.
- Currently 5 projects in commercialization pipeline.
- Side benefits for both sides from professional relationships

Lessons Learned - It's a Partnership!

- Unlike other Chevron Alliances - Los Alamos is not a commercial Service Provider.
- We expect to work jointly with our Chevron counterparts in projects as equal team members. If either Party doesn't have the time and motivation to do the project – then we don't do the project.
- Understanding market conditions helps refocus commercialization efforts
- **Communication** is a key to success.
 - Periodic Oversight and Review
 - Project Leadership
 - Open and Frequent

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THANK YOU!

Please submit your questions in the Zoom Q&A function!

Looking for additional conversation and networking?

Join us in the Peer Connections Lounge after the live Q&A!